# OXYGEN CONTROL REGULATOR FOR AIRPLANES

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The following publication, entitled "Oxygen Control Regulator for Airplanes," is published for the information and guidance of all concerned.

[062.11, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

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# OXYGEN CONTROL APPARATUS.

## 1. USE.

The purpose of this instrument is to provide an automatic control of the artificial supply of oxygen for the pilot and observer. The need of an artificial supply is now well recognized. It has been found that aviators so furnished can do more work and more effective work. The effects of deficient oxygen supply vary considerably with the individual. Some lose consciousness more easily than others, or show other symptons of lack of oxygen under less extreme conditions. It is a peculiarity of the effects that they come on generally without the person being aware of their presence, and if not severe enough to cause unconsciousness they may seriously interfere with his efficient activity.

Physiologists differ somewhat in their opinion as to the exact amount of oxygen which should be supplied, but the specifications recommended by the Bureau of Standards are expressed by the following equation:[1]

$$O=4-\frac{4P}{760}$$

where $O$ represents the flow of oxygen in liters per minute and $P$ is the pressure of the atmosphere expressed in millimeters of mercury. This is based on the experience and investigations of the British flight surgeons. The quantity of oxygen breathed by a man walking moderately at sea level is 4 liters per minute. At an altitude of 20,000 feet, where the pressure is approximately one-half that at sea level, the density of the air will be about one-half as much, so the *weight* of oxygen breathed by a person, not supplied artificially, will be only *one-half* the normal amount. For a pressure of one-half of a standard atmosphere the flow of oxygen as given by the above equation is 2 liters per minute, which is sufficient to make up the deficit.

## 2. CONSTRUCTION.

The full equipment of oxygen apparatus for one man consists of a steel tank (see Specifications No. 27044–A) of $3\frac{1}{3}$ liters capacity, which is charged with pure, dry oxygen under a pressure of 150 atmospheres; the oxygen control instrument; and the mask.

[1] This is sometimes expressed as a rate of 0.0527 liters per minute per cm. "manometer pressure," where "monometer pressure" means the *reduction in pressure* below the normal of 760 mm.

High-pressure tubing of copper connects the flask to the control instrument, and low-pressure flexible tubing (see Specification No. 27077) connects the control instrument with the mask. For two men an extra flask or two flasks are carried, and the two masks are supplied from the same control instrument. However, reports from the Technical Section, American Expeditionary Forces, indicate that this arrangement is not satisfactory, and a separate control instrument for each man is to be preferred.

The oxygen-control apparatus put into production during the war was the French Dreyer model, and was manufactured by the A. C. Clark Co. This is illustrated in Figures I–B and II. The principal parts are the high-pressure gage *b*, reducing valve *c*, distributing valve *d*, the aneroid control valve *e*, the battery of aneroids *f*, and the flow indicator *h*.

The high-pressure connection from the flask is made at *a*. From here the oxygen is led by a branching tube to the gauge *b* and to the reducing valve. The gauge is of the usual Bourdon type. The dial has two scales on it: one indicating the percentage of oxygen left, and the other the pressure of the oxygen in the tank expressed in terms of atmospheres. Just below the gauge is an air-tight space, the bottom of which is a corrugated metal diaphragm, which also forms the roof of the reducing chamber. The opening from *a* is through the floor of this chamber, and just above this is a valve plunger at the end of a lever which is operated by the motion of the diaphragm. The diaphragm is moved up sufficiently to close the valve when the pressure in the reducing chamber is about one atmosphere, that is, 14.7 pounds per square inch. The operation of this valve depends alone on the elasticity of the diaphragm and the air pressure of the closed chamber above the reducing chamber. Since these factors are constant for all external pressures (if temperature effects are neglected), the pressure of the oxygen in the reducing valve is always the same. Hence the volume of oxygen delivered depends on valves *d* and *e*, which will now be described.

From the reducing chamber a tube leads to the distributing valve *d*. This has three positions, (1) closed, (2) one man, and (3) two men. The amount of oxygen let through this valve for two men is 1.6 as much as for one. This is thought to be sufficient, as the probability is small of the two men inhaling at the same time, since the time of inhaling is much less than the time of exhaling.

From *d* a tube leads to the aneroid valve *e*. The action of this valve depends upon the expansion of the battery of aneroids. The piston *g* which moves in the cylinder has a tapering groove cut in the side, so that the farther it is pushed in the larger the flow of gas. The early specifications provided that this valve open at the atmospheric pressure corresponding to an altitude of 6,000 feet. But the

recent requirements have changed this to 3,000 feet. There are seven aneroids in the battery operating this valve. The air has been pumped out of these aneroids, and they are kept from collapsing by internal springs. When the external atmospheric pressure is reduced, as is the case on ascending, these aneroids expand and push the valve piston into the cylinder.

From the valve *e* the oxygen passes through the flow indicator to the low-pressure exit. The flow indicator is a delicate anemometer turbine, which gives a qualitative indication of the flow of oxygen. There are two nipples at the low-pressure exit *i*, one of which is fitted with a valve to be closed when the apparatus is used only by one man.

A cap is provided to close the opening *a* when the instrument is not used. Any dust or dirt getting into the reducing chamber will seriously interfere with the proper operation of the instrument. Moisture also will cause serious trouble. For this reason dry oxygen must be used.

The report of the Bureau of Standards (see Aeronautics Instruments Circular No. 5) states that the Dreyer control apparatus is very erratic at low temperatures, $-25°$ C., the flow falling off to 47 per cent of the required value at 34,000 feet. A report from the Technical Section, American Expeditionary Forces, also indicates that these instruments are not altogether satisfactory.

Another type of oxygen regulator, the Prouty, manufactured by the Van Sicklen Co., has shown up very well in tests made by the Bureau of Standards. The effects of low temperature and low tank pressure are well within the limits required by the specifications, viz., $-10$ per cent and $+15$ per cent.

This apparatus is shown in external form in Figure I–A, and the mechanism by the sectional view of Figure III. The inlet is at *g*, which is connected with the storage tank by high-pressure copper tubing. From *g* the oxygen passes through a capsule *h*, containing a number of 200-mesh phosphor-bronze screens, which serve to keep dust out of the valves, and on through the valve orifice *f* to the high-pressure cage *a*. This cage has for an outer wall a flexible diaphragm *b*, which is connected at its center to the lever *c*. This lever is pivoted at *i* to a lug of the central frame. A spring *d*, acting at the upper end of *c*, keeps the lower end in contact with the jewel valve plunger *e*. Normally *a* is closed, except for the opening *f*. As oxygen from the tank flows in, the diaphragm is pushed out by the pressure and depresses the valve end of *c*, causing the jewel plunger to seat in *f* and to stop the flow of gas. The pressure at which *f* is closed is 50 lbs./sq. in.

The low-pressure valve, shown in the left of Figure III, is similar to the high-pressure valve, but is adjusted so that it closes when the pressure on the inside of the diaphragm $b'$ is 1 oz./sq. in. greater than on the outside. The operation of the diaphragm $b'$ is controlled in part by the aneroid box $k$. To start with, the orifice $f'$ into $a'$ is closed. At higher altitudes the reduced atmospheric pressure allows the aneroid $k$ to expand, and thus exert a pressure on $b'$, which moves the lever $c'$, so that the valve plunger $e'$ is opened and oxygen from the high-pressure side enters $a'$. The gas passes on through $a'$ to the exit $y$, which leads to the gas masks. This opening $y$ is of such size that the requisite number of liters per minute will pass for a given differential pressure in $a'$. Consequently as soon as this rate of flow has been reached a pressure builds up in $a'$, which closes the valve, and as the pressure falls off with the continued flow the valve opens. Thus the valve, by opening and closing, keeps a uniform flow of oxygen for a given differential pressure. By the expansion of the aneroid $k$ this differential pressure is greater at higher altitudes, so the flow is greater. The effect of the aneroid is adjusted by a regulating spring $n$. At sea level there is some space between $k$ and the adjusting screw $l$, so that the expansion of the aneroid does not exert a pressure on $b'$ until an altitude of 3,000 feet is reached.

The flow indicator, Figure I–A, is a delicate pressure gauge, which is connected to the exit $y$ by a branching tube. No gas flows through this, as is the case in the Dreyer type, but it is actuated by the pressure, which is proportional to the flow.

A high-pressure gauge of the Bourdon type, located at the end of the instrument, indicates the pressure of the storage tank.

In addition to the superiority of this instrument as regards temperature and low tank-pressure effects, may be mentioned the small, compact size and the weight, which is one-third that of the Dreyer-Clark regulator.

## 3. INSTALLATION.

The regulator of the oxygen apparatus should be mounted so the pilot may occasionally look at the flow indicator and satisfy himself that the proper supply is being furnished.

Care should be taken to make all unions between the storage tank and regulator tight, that there may be no leaks and loss of oxygen.

Some pilots prefer to hold a tube from the regulator in the mouth rather than use the gas mask, which is more or less uncomfortable.

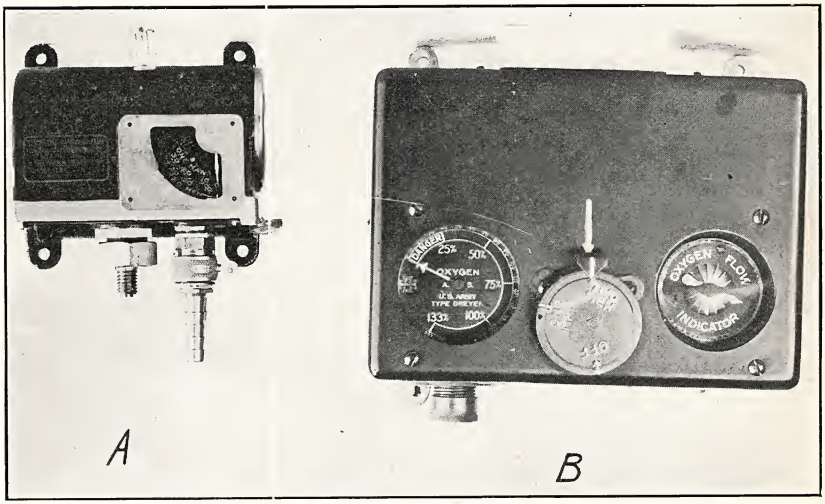


FIG. I.--OXYGEN CONTROL REGULATORS.

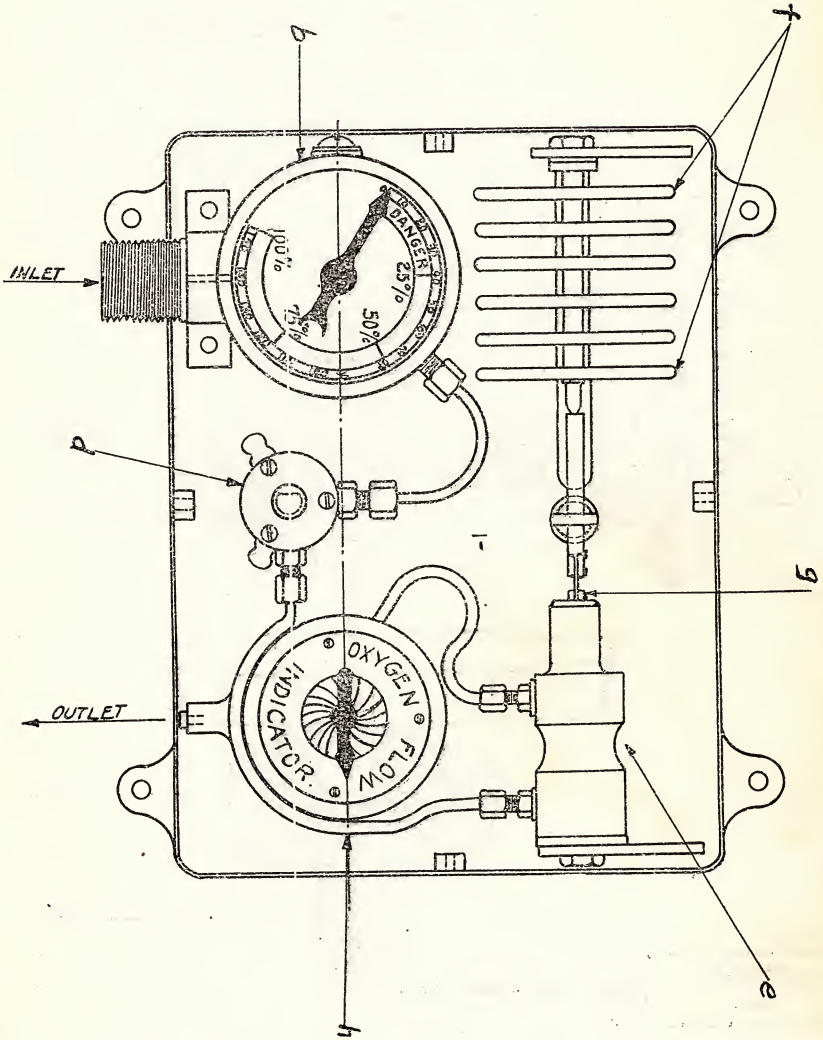
INLET
OUTLET
DANGER
100%
75%
50%
25%
OXYGEN FLOW INDICATOR.
b
f
d
g
e
h

Fig. 11.

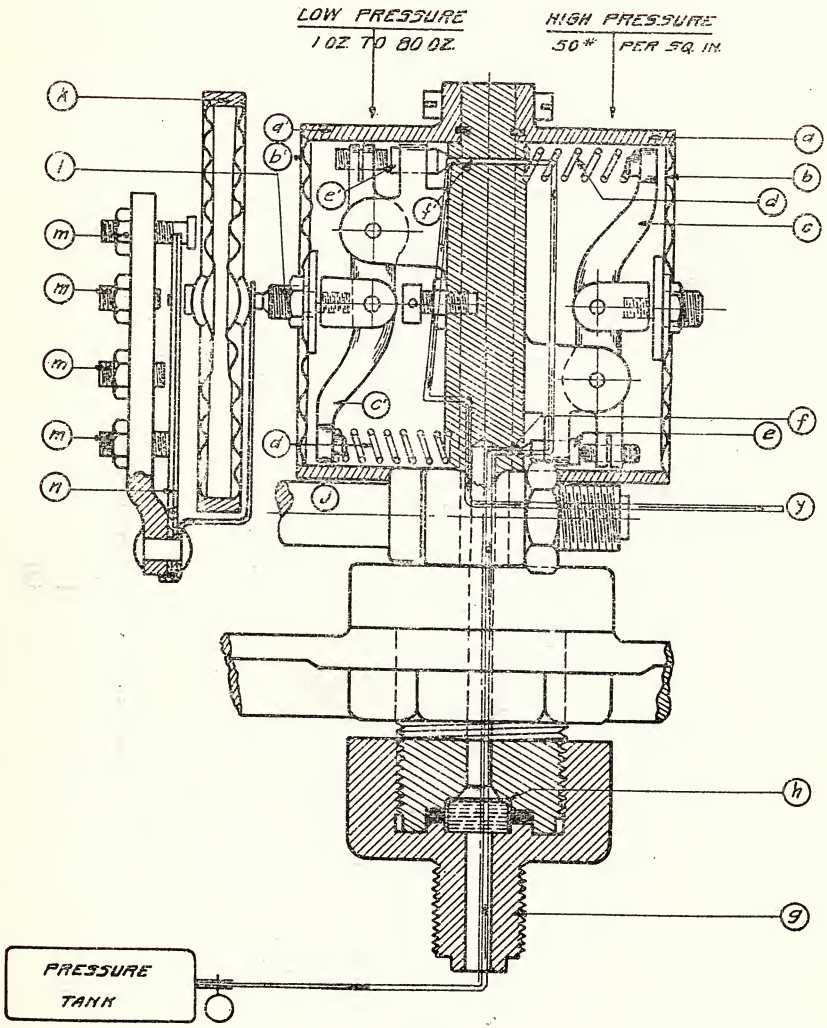
LOW PRESSURE
1 OZ. TO 80 OZ.
HIGH PRESSURE
50* PER SQ. IN.
PRESSURE
TANK

Fig. III.